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A Review on Alternative Refrigerants

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Abstract – Over the past decade, major research was carried out on refrigeration cycles and systems with a specific focus on the substitution of coolant such as R134a by coolant such as hydrocarbons with marginal GWP (Global Warming Potential). In addition to the usage of eco-friendly refrigerants, strategies for improving the performance of the cooler/system have been developed that will also help reduce emissions of GHG (Green House Gases). This paper examines attempts to substitute environmentally harmful HFCs (hydroflurocarbons).

Keywords – Refrigerants, HFCs, R134a refrigerant;

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INTRODUCTION

Refrigeration and air conditioning are more than convenience now a few days. Cold and air conditioning have already become a must with technological progress and changes to climate patterns in the earth's atmosphere. In old days the key objective of cooling was to create ice, used to cool drinks, to preserve fruit, to carry coolers, etc. We now find diverse cooling and air conditioning applications in all areas, such as food processing, preservation and distribution, power plants, vehicles and in commercial and residential convenience.

Refrigeration and air conditioning are becoming very important for humanity, which will adversely influence the fundamental framework of the civilization. Cooling and air conditioning are the main environmental issues, including their potential advantages: ozone-layer degradation and global warming. The loss of ozone is exacerbated by the release to the environment of coolants. The levels of carbon dioxide and methane from human activities are rising at a fast pace from global warming. Direct release of refrigerants represents just around 2% of overall carbon dioxide pollution equal and carbon dioxide emitted by cooling systems power generation is at least ten times the direct result of coolant emission. Refrigeration and air conditioning thus account for about 20% of global warming observed. The development, distribution and usage of chlorinated refrigerants have been phased out in accordance with the conditions of the Montreal Protocol. Therefore, compounds of the lower GWP, such as R-134a, were substituted by refrigerants that had a strong global warming ability (GWP). The task today is to increase device performance, reduce power usage, reduce refrigerant leakage and find environmentally friendly refrigerants.

MEANING OF REFRIGERANTS

Coolants are the job medium for cooling systems that evaporate from the cooled area by collecting heat to ensure a cooling impact. The background of coolant production was based on a range of factors such as protection, stability, longevity, economic or environmental problems, thus promoting modern safety and performance research and equipment enhancement. The coolants may be divided into the following generations. Various generations of coolants have been seen in Fig. 1 and their conduct.

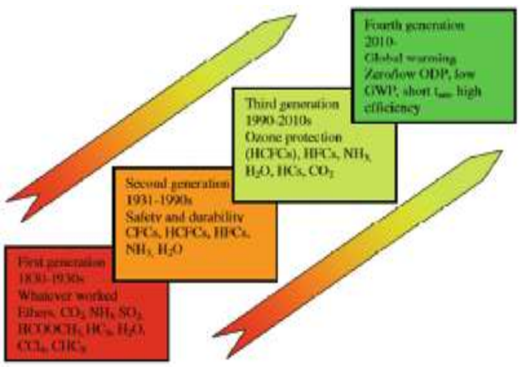

Figure 1: Various generations of coolants

Refrigerants of first generation

The use of natural refrigerants marked the beginning of mechanical cooling, starting at the beginning of the 19th century. The first-generation refrigerants such as methyl chloride, ammonia or sulfur dioxide were used in refrigerators designed during the late 1800s to 1929. For the first hundred years, the common coolants included anything that was worked and available. Flammable, poisonous, or both, almost all first-generation refrigerants is extremely reactive. Following are the properties of certain refrigerants of the first century.

Water is one of the earliest coolants to be used in cooling up to water freezing applications. In applications such as ice slurries, water may be used under the usual freezing point in combination with preventive solutions (e.g. propylene, ethylene glycol) to eliminate freezing. Water has excellent thermodynamic and chemical properties is easily available. In addition to these advantages, technical problems exist due to its high specific volume at low temperatures. These issues include elevated pressure ratios around the converter and high outlet temperature of the transformer.

Ammonia is called R717 and is still a very old coolant used in vapor pressure and cooling systems. Due to its strong importance, high latent heat and fast leakage sensing, R717 offers a reduced molecular weight, a wider range of working temperatures. R717 still has some drawbacks, though. It is very harmful, very annoying and inflammable. Ammonia has a strong water affinity; thus, ammonia is hard to keep dry.

Table 1: Refrigerant properties

Substance	R Number	M (kg/kmol)	NBP (oC)	ODP	GWP
Carbon dioxide	R-744	44.01	-55.6	0	1
Ammonia	R-717	17.03	-33.3	0	0
Sulphur dioxide	R-764	64.06	-10.0	0	0
Ethyl ether	R-610	74.12	35	0	0
Dimethyl ether	R-170	46.07	-25	0	0
Methyl chloride	R-40	50.49	-24.2	0.02	16

Copper and other copper alloys are corrosive as they collect water. It seems to dissociate the use of nitrogen and hydrogen at high discharge temperatures produced by ammonia. Increased overall pressure and power intake of these gasses before entering the condenser are applied to the condensing stress.

Sulphur-dioxide was first replaced by methyl chloride and then more desirable fluoro-carbon refrigerants in the twenties and thirties, becoming one of the most popular coolants used. It is rather toxic but not explosive and flammable. It is not strictly corrosive but creates highly poisonous sulfuric acids and sulfuric acids in conjunction with moisture.

Only used in 1878 was methyl chloride. Methyl chloride is a gently sweetly smelling, colorless, highly inflammable gas. Methyl chloride is a methane-series halocarbon, having many of the desired properties of a refrigerant, which in both domestic and commercial applications have been used widely in the past. Methyl chloride, combined with these materials, Aluminum, copper, magnesium and derivatives are corrosive. Methyl chloride occurs in the presence of moisturizes a weak, ferrous and nonferrous hydrochloric acid that is corrosive. It's exploding, too. In the 1920s, methyl chloride spilled from refrigerators, several fatal injuries happened. The next wave of refrigerants has been discovered here. Few coolants and their properties were shown in Table 1 of first generation.

Second Generation Refrigerants

Chlorofluoro chemicals for protection and longevity were characterized for second generation coolant. The property tables of periodic table elements is examined by Thomas Midgley and his colleagues. They ignored compounds that, based on their low boiling point are brittle, poisonous and cause inadequate volatility and inert gases. In 1928 Midgley and his colleagues made significant finds of chemicals, including charcoal, arsenic, oxygen, sulphur, hydrogen, fluorine, chlorine, and bromine, as regards the flammability and toxicity. The first publication on fluorescent refrigerants showed the consequences, because of chlorination and fluorination discrepancy of hydrocarbons, of the boiling point, inflammability and toxicity of refrigerants. The second generation of coolants was developed by CFC coolants. CFC is a huge, non-flammable, non-toxic gas. It is a pleasant cold, and as it evaporates, it can quickly be compressed to liquid and transports more gas. It is very stable to break it down just through UV rays It is also suitable in a number of applications since it reacts without anything, as well as a pesticide, a fire extinguisher and an aerosol propellant. It fits well in many applications. As it is a single, not a mixture, at different temperatures it does not break up. Along with its thermodynamic properties, some refrigerants of this century are described here.

R-11 is a proven non-flammable and destructive, solid refrigerant. Air conditioning device for small buildings, facilities, department stores, theaters, etc. The system is used. It can be used with the centrifugal compressor in systems where the cooling load ranges from 150 and 2000 tons. The solvent refrigerant R-11, as well as the secondary coolant, are often used. Low pressure and strong ability to deplete ozone layer are the issues with the usage of the refrigerant. Because R11 has the greatest potential for ozone depletion, the usage and development of R11 must be totally stopped under the Montreal Protocol. R-11 is now supplemented by other environmentally sustainable coolants, the most popular of which is R-123.

R-12 is a highly versatile coolant for a broad range of cooling and air conditioning applications. The refrigerant R12 is applied in domestic coolers and freezers as well as water fountains and travel refrigeration, liquid chillers, dehumidifiers, ice producers. R12 is non-flammable, non-explosive and nontoxic. It is now very common for both domestic and commercial use. R12 is extremely stable CFC which even in harsh operating conditions does not disintegrate. Sadly, it is the CFC and unusually highly likely to allow the ozone layer to deplete. Other coolants replace R12 and a number of the proposed substitutions for “R12 are R-134a, R-401a, R-401b”.

In the 1970s, scientists found that CFC isn't innocuous despite decades of pouring over one million tons of the material annually in the air. Professor James Lovelock found that in 1973 Freon was noxious to the coating of ozone. The Sun rays in the stratosphere, chlorine atoms drift loose, dissolve the CFC molecules.

Table 2: Second Refrigerants Properties

Substance	R No.	M Kg/ kmol	NBP (oC)	ODP	GWP
Trichloro fluoro methane	R-11	137.4	23.71	1	4000
Dichloro difluoro methane	R-12	120.91	-29.75	1	8500
Chloro trifluoro methane	R-13	104.5	-81.3	1	11700
Chloro difluoro methane	R-22	86.47	-40.8	0.05 5	1700
R-22/R115	R-502	111.6	-45.3	0.33	5600

They split unstable ozone molecules into oxygen molecules (O3) (O2). Chlorine is not absorbed and ozone has been destroyed for years. Much because stratosphere ozone protects all living things on the planet from ultraviolet radiation. The Montreal Protocol restricted the development and use of CFCs in 1987. The global production of CFCs in the Protocol has come to an end in January 2010. 196 countries signed the Montreal Protocol in 2009. A few coolants and their properties were seen in table 2 in the second century.

Third Generation Refrigerants

Their scope for cooling was mostly poor ozone depletion. Table III lists the properties of different coolants of third generation. A new fluorocarbon refrigerant class named hydrofluoric-olefin (HFO) has been formed with reduced GWP potential. Apart from their low GWP, their principal benefit being that they are suitable for use with current cooling systems. This is fine for industry, but fluorinated gas is also good for consumers. Political demand to control output is increasing, leading to the development of cooling technologies with even lower impacts. The quest then goes on. GWP values for such third-generation refrigerants.

TYPES OF REFRIGERANT

1. Primary coolers: Primary coolants are liquids primarily used as working fluids in vapor compression and steam intake cooling systems. This fluid provides refrigeration via the evaporator phase change process used in stress or absorption systems.

2. Secondary coolants: secondary coolant is a fluid which is used to transport thermal resources from one place to another. Sometimes classified as brines or antifreezes are secondary refrigerants.

CLASSIFICATION OF REFRIGERANTS

1. Fluorinated refrigerants: The degradation by the ozone layer of fluorinated coolants is mainly the cause and contributes to the greenhouse effect. The relations are real but quite difficult between the two phenomena. We discern various types:

i. (CFCs): they are composite molecules of carbon, chlorine and fluorine. It is so secure that they reach the stratosphere without too much difficulty. At this moment, it serves to destruct the ozone layer.

ii. The biomass, chlorine, fluorine and hydrogen ions are HCFC (hydrofluorocarbon). Ozone degrade from CFCs is less secure and less probable. This is known as transient officers.

iii. (HFC): which are substances consisting of carbohydrate, fluorine and hydrogen. They do not contain chlorine and thus do not contribute to ozone layer depletion. This is the substitute substance.

iv. HFO (hydro-fluoro-olefin): R-404A/R-507, R407A/F and R-22 dependent hydro-fluor-olefin (HFO) substitutes R449A is planned for use in commercial and industrial applications with positive direct expansion of low and medium temperature.

2. Mixture of refrigerants: The components can be categorized by their fluorinated form. It is often characterized by the fact that such combinations are:

i. Zeotropic: in a change of condition the temperature changes (condensation, evaporation).

ii. Azeotropics: they function as pure, without any temperature difference as the state changes.

EXPECTED REFRIGERANT PROPERTIES

The characteristics can be divided into thermodynamically, chemical and physically:

1. Thermodynamic Properties

i. Essential temperature and pressure: The coolant critical temperature should be as high as possible above condensing temperature to achieve an increased heat transfer at a stable temperature. If not, too much gasoline should be used by the cooling system.

ii. Basic heat: the liquid can provide as minimal a special heat as practicable. This means that the irreversible grip is small and that the liquid cools more sub-coolly. The special steam heat can, on the other side, be strong to reduce vapor overheating.

iii. Vaporization enthalpy. The area under superheating and region decrease can be minimized due to throttle as widely as possible. In addition, the higher enthalpy value reduces the necessary flow per ton of cooling

iv. Conductance: coolant conductivity should be maximum to ensure that the condenser and evaporator scale is manageable. Ammonia has a higher conductivity from this perspective than R12 or R22, which is better than R22. However, ammonia is poisonous and cannot be used in home cooling.

v. Condenser and evaporator pressure: evaporator temperatures must be above pressure in the atmosphere, otherwise air leakage into the device is possible. Presence of air greatly decreases the capability of the refrigeration device. Often, acids or other corrosive substances can develop because of moisture in the air and this may damage the cooling device tubing.

vi. Compression Ratio: The ratio of coolant leakage around the piston should be as little as practicable. The volumetric effectiveness is also impaired.

vii. Freezing Point: that should be as minimal as practicable or blocking of the passages across the evaporator during the flow of fluid.

viii. Refrigerant amount Handled by ton of cooling: this should be as minimal as possible to have a small compressor size. The compressor shape is determined in this value. A compressor is suitable for reciprocal refrigerants like R12, R500, R22, etc. For other systems like R11 and water, a centrifugal compressor is required for large volumes.

ix. Efficiency coefficient: performance coefficient or COP directly affects the working costs of the cooling device. Increased COP magnitude, reduced operating costs. Since the Carnot COP restricted the COP of any cooling device, a multi-stage cooling system could be used for high operational pressures. CO2 has a rather poor COP. It is not therefore appropriate for usage as a coolant.

x. Mass: The coolant should have maximum density. The pressure increase is achieved by pushing the entangled fluid through the piston-cylinder assembly in reciprocal compressors. The scale of the cylinders therefore depends on the density. The pressure increase is again associated with the density of the steam in centrifugal compressors. A high-density benefit increases high pressure.

xi. Compression: if a coolant is squeezed the temperature of the cooling mechanism is raised and the combustion chamber of the compressor is heated. Compression Temperature External cooling of the cylinders is needed to avoid volumetric and material losses. Refrigerants are also higher than those with the lowest compression temperature.

2. Chemical Properties:

i. Material stability and inertness: chemical stability with temperature operational ranges. It should also not react with or into contact with the materials of the cooling device. In addition, it can be chemical inert and not be polymerized in lower or higher temperature ranges.

ii. Rubber or plastics action: in the cooling mechanism the rubber and plastics are applied thoroughly. The most common use of these materials is in cooling systems seals and gaskets. They help prevent coolant leakage and ensure that the compressor functions smoothly. The coolant should not respond to them or refrigerant leakage from the device or failure of compressor operation may occur.

iii. Flameproof: The cold must be sterile and cannot be fired if the temperature is strong. CO2 is best suited from this point of view, since not only it is not flammable, it is a fire extinguisher as well. It's particularly unwanted to catch flames, and Ethane, butane, isobutene.

iv. Oil effect: The coolant does not respond with a lubricating oil because, because of either thickening or thinning, a lubricating operation is likely to be lost. The viscosity of the lubricating oil should not be soluble in the oil otherwise.

v. Product Effect: if a refrigerant is used directly to cool, the commodity maintained in a heated space may not be affected. Furthermore, the coolant will not damage the commodities if leakage happens while direct cooling is not used.

vi. Toxicity: refrigerant air conditioning, food preservation, and so forth, cannot be harmful when it comes in touch with people.

3. Physical Properties:

i. Detection and Leakage: As pressure outside the atmosphere is normally used in cooling systems, refrigerant leakage may occur after long operating time. This leak should be detected early, or the device would run at a lower capacity or completely cease working. It is also desirable that the coolant smells pungent such that the fluid can be immediately identified.

ii. Fluid mixture: The refrigerant must not be mixed with the oil or the lubricating force would decrease.

iii. Viscosity – The strain falling in the system should be as minimal as practicable. Viscosity: A low-viscosity coolant would take less energy to circulate via the cooling device

REFRIGERANT NEXT GENERATION

R-134a

R-134a is the first fluorocarbon refrigerant to be marketed and does not deplete ozone. Developed about 25 years ago to have R-12-like properties, R-12 is used for medium to high-temperature uses. Due to its low hose permeability and strong critical temperature, R-134a is used in vehicle air conditioning. R-134a is also used for domestic cooling machines. Most coolant manufacturers have R—134a.

The benefit of R-134a is that it is a single-component refrigerant and thus has no glide. Furthermore, the R-134a direct HGWP is minimal. This is the drawback of R-134a in comparison with R-22. For this refrigerant, a system must be far larger to minimize pressure drops and maintain fair operating efficiencies in all the tubing used in and across heat exchanges. In combination with the larger compressor movements required, it results in an unit that is more costly than today's R-22 systems. The coefficient for the R-134a heat transfer is also less than the coefficient for R-22, and tests show that the performance of the machine degrades as used.

This could not be the case for major industrial devices, such as R-11 and R-12 with big screw systems, centrifugal systems and coolants. Here R-134a will offer HFC a fairly thin, straightforward refurbishment approach.

In medium and high-temperature applications R-134a cooling strength and energy usage have proved to be comparable to R-12, according to Emerson laboratory and field trials. R-134a is lost for many causes at evaporative temperatures below -10 ° Fahrenheit (-23 °C):

- Power and efficiency losses relative to R-12 were major.
- High pressure ratios, compromise the efficiency of the compressor.
- Sub-atmospheric (i.e. vacuum) low side pressures result in problems with device stability.

Emerson believes that the R-134a has the same shortcomings as the R-12, but for potential ozone depletion, which is a backward step for most industrial cooling and air conditioning applications. These shortcomings involve larger compressors and tubes with a larger diameter than those needed for use with high-pressure coolants.

For applications over 10-degree Fahrenheit (-23 degree centigrade), Emerson has built product lines for customers looking to use R-134a.

R-404A refrigerant

The machine manufacturers use R-404A as HFC refrigerant as long-term substitute for R-50. The R-404A is an optimal, low and coolant medium-temperature due to its high energy efficiency and zero-ozone reduction ability. A near-azeotropic blend of R-125, R-143a and R-134a HFC refrigerants is R-404A. It is sold from different stores and is the most popular refrigerant in its class.

R-507 refrigerant

This coolant is a mixture of R-143a and R-125 and it has properties similar to R-502. Emerson compressors for R-404A have been authorized for the R-507 (except for some hermetic reciprocal models). R-404A and R-507 run at slightly higher temperatures and slightly lower leakage temperature than R-502.

R-407C refrigerant

R-32 R-125, R-134a is a mixture of R-407C. R-407C has been configured to operate in a similar manner to R-22 for the higher temperature HFC choices. The key problems of the R-407C are its high glide (10 degrees Fahrenheit) and its efficiency loss as compared to the R-22, while this coolant is the best way to convert the HFC options. R-407C has been a popular alternative for producers in systems in which glide is ideal for quickly transformation to an HFC replacement. The lower output of this coolant will, however, in the long term, render the R-410A less desirable for medium and high temperature applications.

When applying R-407C, care should be taken in all applications where glide can affect the output of systems Divided architectures flooded or multi-evaporator. In addition, R-407C cannot be considered as a drop in with or implementing R-22 programs. Like other HFCs, R-407C needs POE lubricants and other software design changes might be essential for R-407C to operate in R-22 systems in an acceptable manner.

R-407A refrigerant

R-407A is a combination of R-32, R-125, R-134a in 20/40/40 by mass. The R-407A is designed for low and medium temperature cooling applications. R-407A, with an iPCC4 GWP rating of 2107, is 54% smaller than R-404A. This refrigerant is said to be strongly combined with power and reliability for R-22, which makes it better suited for retail and food storage R-22 retrofit systems. The R-407A is smaller than R-22, but the pressures on the system are greater. Compressor cooling should be taken into consideration for high atmospheric operations.

R-32 refrigerant

R-32 is a slightly inflammable HFC refrigerant of ASHRAE 34 classifications of A2L for inflammability. The part in R-410A is better known. R-32 is still not sold in North America as an independent refrigerant but is becoming more and more involved in China.

R-410A refrigerant

R-410A has been the preferred coolant used in the field of domestic air conditioning. The R-410A model ranges are offered by most leading residential air conditioning companies. R-410A has improved TEWI performance than other solutions. The coolant also has many advantages, which makes it an excellent coolant for industrial cooling applications.

All R-22 and R-410A refrigerants there are some distinct operational variations. R-410A works at a pressure 50% more than R-22, but a higher pressure allows the system to operate at a lower temperature. In order to be able to acquire the right joint fretting and reparation tips for this refrigerant, everybody operating these devices needs to be educated on the new technical aspects of R-410A systems.

R-410A is a 50 percent R-32 and 50 percent R-125 quasi-azeotropic composition. Systems research showed that the system performance R-410A is better than that of the R-22. With a coefficient of 35% greater heat transfer and 28% lower pressures relative to a coefficient of R-22, R-410A evaporates.

Due to the fact that R-410A systems were developed specifically to use less ropes and less tubes, R-410A was designed as an economical coolant. The efficiency of the R-410A is also contributed by lower material and lower refrigerant charges and improved cyclic output.

A high-pressure coolant was known to be R-410A. High-pressure coolant functions well above those usually found in coolants such as R-22 and R-502 at pressures. The retrofit refrigerants for old equipment cannot be used, they are only intended for modern devices (including compressors). Compressors R-22 with these higher pressures cannot comply with UL and market specification requirements.

R-417A refrigerant

A "drop-in" refrigerant was created for fresh and service substitutions of R-22, when utilizing conventional HCFC lubricants, such as mineral oil and alkyl benzene (AB). It is a mixture of R-1125 (46.6%), R-134a (50%) and R-600 Butanes. This coolant comes under the brands ISCEON® 59 and Nu-22 TM (3.4 percent). To improve oil return, the hydrocarbon in the mixture was applied. ASHRAE identifies the coolant as A1/A1 and is non-toxic and non-flammable. In comparison to R-22, the refrigerant manufacturer promises equal power and increased performance. It also states that R-22 grains could be retained, but advises that existing guidelines be taken in conjunction with the device and compressor maker.

The manufacturer's accuracy statements for R-417A do not rely on independent test results. Independent tests on R-417A showed a lower device capability of between nine and 10 percent for use as a drop-in coolant. The same test shows a loss of efficiency of between 3 and 5%. Independent R-417A testing have demonstrated substantial oil revert delays.

The R-417A presents two additional problems. The refrigerant at GWP ratings is less than R-407C and R-22. R-417A has the same issues of separating and glide in a mixture as R-407C. The structure and properties of this coolant may therefore be greatly affected by a device leak.

Emerson Climate Technologies in HFCs to R-22 is not anticipated to be a big option for the R-417A. Emerson may not have a detailed evaluation of the R-417A coolant or is not officially approved to be included in our compressors or parts.

R-152a refrigerant

R-152a is like R-134a, but, separated from the climate. It has a significantly less GWP than R-134a (120 vs. 1.300), but is considered inflammable as ASHRAE A2. In the car-air conditioning system R-152a is used as an alternative to replace R-134a, R-152a is not a major choice for commercial cooling systems due to its thermal stability.

R-422 refrigerants

Other HFC refrigerants designed for the replacement of R-22 are R-422A, R-422B and R-422D. Both R-422 coolants have the same coolant mixture. The last letter actually means very different ratios of the coolant blends. A combination of R-125 (85%), R-134a (11.6%) and R- 600 an are marketed as 1 Shot TM or 1 ISCEON Series 9 and are composed by (3.4 percent). To improve oil return, the hydrocarbon in the mixture was applied. In comparison to R-22, coolant manufacturers claim equivalence and efficiency. They also say it is possible to maintain R-22 lubricants, but recommend consulting the system and compressor manufacturer with regard to present applications.

CONCLUSION

The Montreal and the Kyoto Protocols state that R12 could have been phased out by 2010 by updating all this research work and by studies of different thermodynamic effects of the refrigerants, as set out in a Different Research Paper. Because of their low global wear worming potential (GWP) and nil ozone depletion potential, R600a, R290 and blends of R290 and R600a are the best alternative in domestic cooling (ODP).

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